JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Allocation and sizing of DG in the Distribution System Using the Cuckoo Search Algorithm

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Abstract: - The power networks around the world are anticipated to be significantly impacted by distributed generation (DG). The deployment of DGs in the distribution network benefits from loss reduction, backup power supply, and real, reactive power management, all of which increase network dependability. Among the many goals of this effort that are restricted by equality and inequality are power loss minimization, voltage profile improvement, and operational cost minimization. For the purpose of demonstrating the suggested strategy, 33 bus radial distribution test systems have been employed. The appointment of type 1 DGs (only real power injection), type 2 DGs (both real and reactive power booster), and type 3 DGs are three isolated cases for which each test is considered (only reactive power injection). The simulated results of the suggested method are compared to those of other well-known techniques.

Keywords: DG placement, SIA, CSA, optimal location and sizing of DG, power loss reduction and voltage stability improvement, radial distribution system, operating cost minimization, MATLAB.

Introduction

One of the most compelling reasons for research on the integration of distributed energy resources to the power grid is the use of renewable energy sources such as solar, wind, biomass, hydro, geothermal, and ocean energy. Clean, primary, or endless energy that is reduced in size and dispersed around the planet is what constitutes renewable energy in its most basic form [1]. Therefore, the only way to access these resources is through their inclusion in the distribution network through Distributed Generation (DG)[2].

Despite the fact that there is disagreement over the precise meaning of "DG," there have been some notable definitions of the idea in the literature [3]. DG is a small-scale source (10 to 10,000 KW) that is typically directly connected to the power grid close to the location of the end consumers and is not centrally planned or dispatched [4]. In the study of power production, it is anticipated that GD will play a significant role and develop into one of the most alluring research fields. This constant focus on potential benefits and advantages, rising electrical demand, and technical and financial limitations on the development of new power plants and transmission lines are all factors [5].

The main motives for the increasingly common usage of DG can be described as follows:

i. Minor generators like DG are easy to find the site for setting up.
ii. Modern technology has made existing plants ranging in capacities from 10KW to 15KW.
iii. DG units are nearer to customers, Transmission and distribution (T&D) cost can be ignored or reduced.
iv. Natural gas, regularly used as fuel in DG is distributed almost everywhere, and stable prices are expected for it.
v. The Investment risks of DG are low and require shorter installation times.
vi. DG suggestions wide ranges of grouping in terms of cost and consistency to select by engineer developers.

A new voltage-stability index is introduced by simplifying load-flow equations to seek the most sensitive buses to voltage collapse in radial networks. But, no DGs are exhibited. Short of DG penetration, an equivalent two-bus distribution network system for voltage stability improvement is presented. Bus indices for considering the effect of aggregated DGs on the voltage security of a transmission grid are developed without considering the behavior of radial distribution networks. Some work has been proposed for optimal placement of the DG to minimize power losses in the system [6]. A DG allocation algorithm is presented for voltage profile improvement and power loss reduction on a radial feeder with a non-uniformly distributed load; however, the load variability is not considered. Besides, the minimization of the cost of energy losses is a better representation of the utility benefit.

With the goal of mimicking animal problem-solving abilities, branches of nature-inspired meta-heuristics known as swarm intelligence have gradually gained popularity. Particle swarm optimization, artificial bee colony optimization, ant colony optimization, etc. are some of the famous algorithms that mimic animal behavior in problem modelling and solution. In this paper, we present the Cuckoo Search Algorithm (CS), a new population-based search algorithm. Stimulated by the motivating brood freeloading breeding behavior of convinced species of cuckoos, is presented to assess the DG site and size in the distribution system. Using CS, the optimization can be solved efficiently, partly because there are fewer parameters to be fine-tuned in CS than in other optimization algorithms. Simulation effort is carried out on a 33-bus radial distribution feeder to authorize the efficiency of the proposed way. Results showed that CS is capable of handling complex optimization problems and gives better-quality solutions with a higher precision factor compared to GA and PSO methods.

The idea of this paper is mainly due to the attractiveness and simplicity of the cuckoo search algorithm. The arrangement of the paper is briefly discussed, the second chapter details the problem formulation, and the following section provides the detailed procedure of the three algorithms in the continuous sections, followed by the results and discussion in the following chapter after the algorithms, and the final chapter is the conclusion.

2.Problem formulation

This section deals with DG allocation for balanced distribution system. To do the objective functions, DG limits, Voltage limits and the load flow solution method is to be started.

2.1 Objective Function

The objective function for the balanced system isdefined as

$$\min (P_{loss}) = \sum_{i=1}^{n} {I_i}^2 R_i \quad (1)$$

where, i is the bus number, I_i is the branch current, R_i is the branch resistance and n are the number of branches.

2.2 Constraints:

The constraints are

Voltage Constraints:

$$0.9 \leq V_k(pu) \leq 1.1 \quad (2)$$

DG limits:

$$60 \leq P_{DG} \leq 1500 \quad (3)$$

2.3 Load flow solution:

J.H Teng proposed a new load flow method of analysis for radial distribution system. Matrices called BIBC and BCBV has been developed which describes relationship of bus injection to branch current and branch currents to bus voltage is written as [7]

[B] = [BIBC] [I] (4)

[ΔV] = [BCBV] [B] (5)

Combining (4) and (5) we get

[ΔV] = [BCBV] [BIBC] [I] (6)

[ΔV] = [DLF] [I] (7)

The load flow solution of the distribution system is obtained by solving below equations (10), (11) and (12) iteratively.

$[{}^{I}Ii^{k}]=(Pi+jQi)/(Vi^{k})^*$ (8)

$$[\Delta V_{k+1}] = [DLF]\,[I_k] \quad (9)$$

$$[\Delta V_{k+1}] = [V_\circ] - [\Delta V_{k+1}] \quad (10)$$

2.4 Voltage Stability Index:

In a radial distribution system, each receiving node is supply by only one sending node. When DG is linked to distribution system, the voltage stability index (VSI) which was accessible by Charkravorty and Das, will be transformed. Equations used to formulate this index are presented in, to solve the load flow for radial distribution systems. By using Eq. (4) and Eq. (5), Eq. (6) which represents the VSI is formulated as:

$$I_{ni} = \frac{V_{mi}-V_{ni}}{R_{ni}+jX_{ni}} \quad (11)$$

$$P_{ni}(ni) - jQ_{ni}(ni) = V_{ni} * I_{ni} \quad (12)$$

$$VSI(ni) = |V_{mi}|^2 - 4[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}]|V_{mi}|^2 - 4[P_{ni}(ni)R_{ni} + Q_{ni}(ni)X_{ni}]^2 \quad (13)$$

where V_{mi}, is the sending node voltage; while V_{ni}, P_{ni}, Q_{ni}, R_{ni}, and X_{ni} are voltage, real power, reactive power, resistance, and impedance for the receiving node [8].

The index is modified to become an objective function for improving VSI, as follow:

$$f_2 = \frac{1}{\min (VSI(ni))} \quad n_i = 2,3, \dots, n_n \quad (13)$$

where VSI (ni) > 0 for i = 2, 3..., n, so that a feasible solution is existed. It is very essential to recognize weak buses for nodes with minimum VSI that are disposed to voltage instability. Inspecting the VSI performance exposes that the buses which undergoing huge voltage drops are weak and within the condition of corrective actions.

2.5 Cost of energy loss reduction

Initially, the load flow solution for the test system is solved without DG to read real power losses and again the process is represented the net loss reduction given through equation[9].

$NLR = P_{loss} - P_{loss,\,DG}$ (14)

where *NLR* = net loss reduction, P_{loss} = power loss of the system without DG, *and* $P_{loss;\,DG}$ = power loss of the system with DG. The obtained loss reduction with DG is converted into cost value.

C_{NLR} ¼ NLR × ðCost of energy saving=kwhþ× 8760 (15)

The invested cost of optimally placed solar PV-type DG is calculated

$C_{DG;\,Inv}$ ¼ ð*DG size* × ð*DG* Investment *Cost*=kwh (16)

The economic validation of the above discussed objective function depends on the optimal location andrating of DG.

2.6 Case study

In fact, three test cases are considered in this study. Three different types of DG applications represent first test case and second test case respectively [10]. Type 1: DG is accomplished of supplying only real power, for immediate, photovoltaic and microturbines. Type 2: DG is capable of supply real and reactive power. Gas turbines based synchronous generator such as biomass can be included. Type 3: DG is capable of supplying only reactive power. In this study, the type 2 DG is providing real and reactive power support. Each test cases has include single and multiple DG unit installation. In this study, the maximum DG allowed to be implemented within the network is only two units.

Cuckoo Search Algorithm

Cuckoo search (CS) is an optimization algorithm inspiredby the brood parasitism of cuckoo species, which lay theireggs in the nests of other host birds. CS is proposed by Yang and Deb in 2009 [14], and it has been applied into the engineering optimization problems and shown its promising efficiency. For instant, in solving the welded beam design and spring design problems, CS achieved better quality solutions compare to existing algorithms in [15]. If a host bird discoversforeign eggs in its nest, it will either abandon the nest and build a new nest elsewhere or simply throw the foreign eggs away. A cuckoo egg cell represents a new explanation while to each hostbird egg in a nest denotes a solution. The aim is to replace a worst solution in the nests with the new and possibly better solutions. In this study, the simplest approach is used where each nest has only a single egg, even though the algorithm canbe extended to handle multiple eggs case.

For ease in describing CS, the three idealized rules are described as follows.

i. At one time, each cuckoo only lays one egg, and leaves it in a randomly chosen nest;

ii. The algorithm will carry over the best nests with high-quality eggs (solutions) to the next generations;

iii. A host bird can discover a foreign egg with a probability, $p_a = [0,\ 1]$ while the number of available host nests is fixed in this case, the host bird can either abandon its nest and build a completely new nest elsewhere or simply throw the eggs away.

When generating new solutions $x^{(t-1)}$ for a cuckoo I, a Levy flight is performed.

$$X_i^{(t+1)} = x_i + \alpha \oplus \mathrm{Levy}(\lambda)$$

Where $\alpha > 0$ is the step size which should be associated to the problem of interest's scales; α can be set to value 1 in most situations. is basically the stochastic equation forrandom walk, which is a Markov chain whose next status or location only depends on the current status or location, and the transition probability, which are the first and second term respectively [11]. The product represents the entry wise multiplication, which is similar to those used in PSO. In terms of exploring the search space, random walk via Lévy flight is more efficient as its step length is much longer in the long run. The random step length of Lévy flight, which fundamentally provides a random walk, is derived from a Lévy distribution with an infinite variance and infinite mean.

$$\mathrm{Levy} \sim u = t^{-\lambda}$$

Here, the consecutive hurdles of a cuckoo essentially form a random walk development with a power law step length distributionwith a heavy conclusion. Numerous new solutions should be generated by Lévy walk near the best solution obtained, since this procedure will speed up the local exploration. However, toconfirm the algorithm will not be trapped in a local optimum, a substantial part of the new solutions must be generated through far field randomization, so that the locations would be sufficiently far from the current best solution.

Cuckoo Search for Distributed Generation placement:

The implementation of CS for optimal siting and sizingDG problem entailed the determination of several steps of procedure as presented for the CS parameters setting, number of nests, $n=20$, step size, $\alpha=1$, and the probability to discover external eggs, $P_a=0.6$ have been practical in this study. On the other hand, network topology based on forward/backward sweep algorithm was used for load flow analysis to evaluate the objective function, due to its computational effectiveness, low memory consumptions, and robust convergence characteristic [13].

i. *Step 1*: Initialize population

The CS must be provided with the population number, n and the initial range of host nests at the start, which can be specified by the user. If the user not suggests any initial range, the algorithm will create an initial population with the default value. The initial population will be evaluated using the objective function, which is the driving force behind CS.

ii. *Step 2*: Generation of cuckoo

A cuckoo is randomly generated by Lévy flight. The cuckoo is evaluated using the load flow and objective functions to determine the quality of the solution.

iii. *Step 3*: Replacement

A nest is selected among n randomly, if the quality of new solution in the selected nest is better than the old solution, it will be replaced by the new solution (cuckoo).

iv. *Step 4*: Generation of new nest

The worse nests are abandoned based on the probability (P_a) and new ones are built.

v. *Step 5*: Termination

In this study, the stopping criterion is set to tolerance value of $1e^{-6}$ and maximum generation of 100 iterations. After satisfied the stopping criterion, the iteration will be stopped and the result of CS will be obtained.

SIMULATION RESULTS

The proposed method is verified on a 33-bus radial distribution system as illustrated. The power of all network buses is assumed to be delivered by the substation placed at node 1. The total real power loss on the 33 radial distribution system is 0.201MW. calculate the cost of DG placement on each type.

In order for directly obtained the optimal siting and sizingof DG in the distribution system with the target of minimizing the total real power losses and improve voltage stability while maintain the acceptable voltage limit, the Cuckoo Search algorithm was used, which is a self-developing code, built using MATLAB script functions.

Table 1Simulation Results of DG sizing using PSO & CSA at different test cases for multiple DG

DG Type	SYS no:	DG loc		Algorithm	Real Power loss(KW)	Energy Loss (Mega Joules)		DG Cost In Rupees $\times 10^4$		DG sizing(MVA)		Percentage loss reduction(%)
NA	33	NA		Base Case	211.078	8.5611		NA		NA	NA	NA
						Energy loss converge by dg1	Energy loss converged by (dg1+dg2)	Cost of dg1	Cost of (dg1+dg2)			
1	33	6	30	PSO	91.23	4.818	3.7815	2.6077	3.936	1.3038	0.6642	56.77
2	33	6	30	PSO	39.74	3.8487	1.0122	2.5613	4.5858	1.2806	1.0122	81.17
3	33	6	30	PSO	142.151	6.3409	5.7655	2.8285	3.8726	1.4142	0.5218	32.65
1	33	6	30	CSA	90.77	4.818	3.7002	2.6077	3.7697	1.3038	0.5810	56.99
2	33	6	30	CSA	38.51	3.8487	1.612	2.5613	4.3734	1.2806	0.9061	81.75
3	33	6	30	CSA	141.778	6.34	5.7504	2.8285	3.8176	1.4142	0.4946	32.83

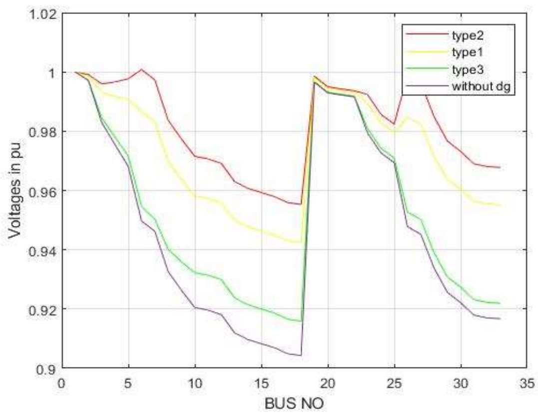

Figure 1Voltage profile for different test cases on PSO

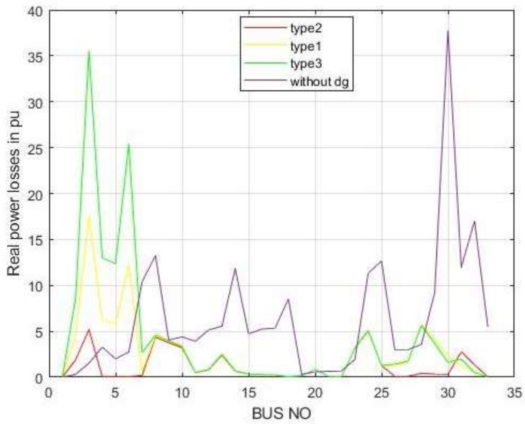

Figure 2Real power losses for different test cases on PSO

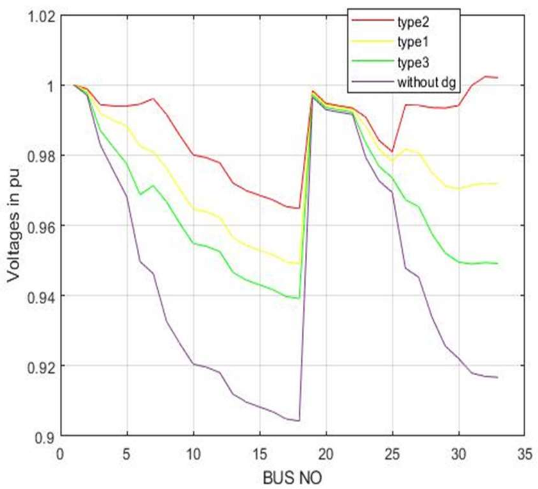

Figure 3Voltage profile for different test cases on Cuckoo search

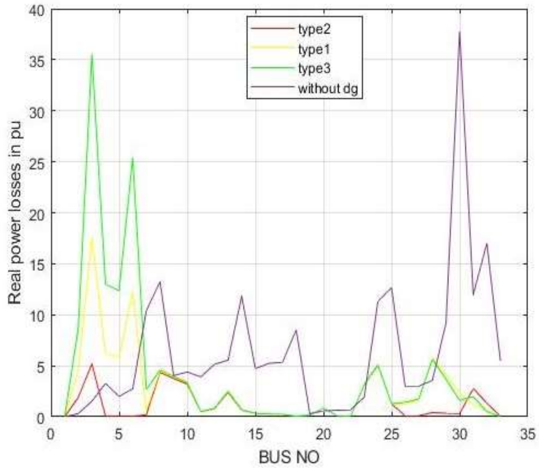

Figure 4Real power losses for different test cases on Cuckoo search

CONCLUSION

A Cuckoo Search algorithm (CS) for DG placement and sizing problem in the radial distribution system to reduce total real power losses and improve voltage stability with imposed voltage constraint is presented in the paper. The CS offers both optimal position and sizing of DG as the productions. It is demonstrated that the proposed method is capable of saving a significant amount of power, attain improvement in voltage stability, and voltage profile by comparing the results among pre and post installation of DG and calculate the cost at each test cases gives the minimization of maintenance cost. On the other hand, CS outperforms and SIA in terms of generating high-qualitysolutions. However, in practice, the best location or size may not always be possible due to other practical constraints. For example, the optimum size for certain resources of DG maynot be available in the market. In the present study, the other advantages such as the economic and environmental aspects ofDG are not considered. In addition, the application of CS in combination with other algorithms may also create aninteresting area for further research.

References:

[1] X.-S. Yang and S. Deb, "Cuckoo Search via Lévy flights," in Nature & Biologically Inspired Computing, 2009. NaBIC 2009. World Congress on, 2009, pp. 210-214.

[2] F. A. Farret and M. G. Simoes. (2006). Integration of alternative sources of energy.

[3] G. Celli, E. Ghiani, S. Mocci, and F. Pilo, "A Multi objective Evolutionary Algorithm for the Sizing and Siting of Distributed Generation," IEEE Transactions on Power Systems, vol. 20, pp. 750- 757, 2005.

[4] A. Hamouda and K. Zehar, "Efficient Load Flow Method for Radial Distribution Feeders," Journal of Applied Sciences, vol. 6, pp. 2741- 2748, 2006.

[5] N. L. Panwara, S. C. Kaushikb, and S. Kotharia., "Role of renewable energy sources in environmental protection: A review," Renewable and Sustainable Energy Reviews, vol. 15, no. 2, pp. 1513-1524, 2011.

[6] P. N. Vovos and J. W. Bialek, "Direct incorporation of fault level constraints in optimal power flow as a tool for network capacity analysis," IEEE Transactions on Power Systems, vol. 20, pp. 2125-2134,2005.

[7] G. Celli and F. Pilo, "MV Network Planning under uncertainties on Distributed Generation penetration," Power Engineering Society Summer Meeting, 2001 vol. 1, pp. 485-490, 2001.

[8] T. Ackermann, G. Andersson, and L. Soder, "Distributed generation: a definition," Electric Power Systems Research, vol. 57, pp. 195-204,2001.

[9] M. Chakravorty and D. Das, "Voltage stability analysis of radial distribution networks," International Journal of Electrical Power andEnergy Systems, vol. 23, pp. 129-135, 2001.

[10] C. Wang and M. H. Nehrir, "Analytical Approaches for Optimal Placement of Distributed Generation Sources in Power Systems," IEEE Transactions on Power Systems, vol. 19, pp. 2068-2076, 2004.

[11] X.-S. Yang and S. Deb, "Engineering Optimisation by Cuckoo Search," Int. J. Mathematical Modelling and Numerical Optimisation, vol. 1, pp. 330-343, 2010.

[12] D. Gautam and N. Mithulananthan, "Optimal DG placement in deregulated electricity market," Electric Power Systems Research, vol. 77, pp. 1627-1636, 2007.

[13] S. K. Injeti and N. P. Kumar, "Optimal Planning of Distributed Generation for Improved Voltage Stability and Loss Reduction," International Journal of Computer Applications, vol. 15, pp. 40-46, 2011.

[14] A. Hajizadeh and E. Hajizadeh, "PSO-Based Planning of Distribution Systems with Distributed Generations," World Academy of Science,Engineering and Technology, vol. 45, pp. 598-603, 2008.

[15] D. Karaboga and B. Akay, "A comparative study of Artificial Bee Colony algorithm," Applied Mathematics and Computation, vol. 214(1), pp. 108-132, 2009.